

## A possible mutualistic interaction between vertebrates: frogs use water buffaloes as a foraging place

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**Abstract.** Mutualisms shape biodiversity by influencing the ecology and the evolution of populations and communities. For example, among many others, birds commonly forage in association with large mammals, including livestock, but so far no similar relationship has been described for amphibians. In this note we describe the association between the Marsh Frog (*Pelophylax ridibundus*) and the Anatolian Water Buffalo (*Bubalus bubalis*) in Turkey and provide possible explanations for the existence of direct relations between these representatives of two vertebrate classes. We hope that our note stimulates future research on this subject.

**Keywords.** *Bubalus bubalis*, interaction, *Pelophylax ridibundus*.

Interspecific interactions such as mutualism are main processes that shape biodiversity by influencing the ecology and the evolution of populations and communities (Bascompte, 2009; Sazima et al., 2010). Among many others, birds commonly forage in association with large mammals, including livestock, wild ungulates and pachyderms (Dean and MacDonald, 1981; Sazima, 2011). In particular, associations with cattle and buffaloes are one of the best known and occur in many geographical regions (Bradshaw and White, 2006; Sazima, 2011). However, searching through different kinds of scientific information sources, we did not find any records on similar relationships between amphibians and large mammals. Thus, the purpose of this note is to describe the association of the Marsh Frogs (*Pelophylax ridibundus*) and the Anatolian Water Buffaloes (*Bubalus bubalis*) in Turkey and to provide a possible explanation for the existence of direct relations between these representatives of two vertebrate classes.

The observations were carried out in the Kızılırmak delta (N Turkey) that stretches along the Black Sea coast from 41°30'N and 41°45'N to 35°43'E and 36°08'E. The delta is one of the largest wetlands in the Middle East and an important area for migratory birds (Erciyas-Yavuz et al., 2015). The delta is located at an altitude between 0 to 15 m above sea level and its total surface area is about 56,000 ha. While 70% of the delta is intensively used by people, the remainder is a natural habitat including open water, freshwater and semi-saline lakes, marsh vegetation, sand dunes, woodland, and farmland, including pastures for the local buffalo race (Barış et al., 2005). Anatolian Water Buffaloes play a major role in structuring the vegetation in the Kızılırmak delta, including its permanent and ephemeral wetlands and adjacent coastal sand dune systems. They stay outside during April-November and the rest of the year they are kept in farms (Sullivan et al., 2016).

To confirm the rarity and novelty of our observations, we searched information on possible relationships

between frogs and buffaloes, domestic cattle and similar large mammals using the internet-based search engines of Thomson-Reuters (Web of Science, Zoological Record) and Scopus databases, Google Scholar and Google Books. Additionally, we searched for amphibian and mammal (generally, and specifically frog and buffalo) records in previously undescribed sources including internet web searches for trip reports, images and videos carried by Google, Google images, Flickr and YouTube. We searched not only the English and Latin but also included numerous other languages.

Browsing internet graphic sources and searching for the sitting frogs on buffaloes, four photographs were found. Three were from south Asia and one from Hungary. In all cases these were single buffaloes with the head protruding out of the water, where frogs were present but no insects were observed. No data about the described phenomenon were found in other sources including scientific on-line databases.

Real data in the field were also collected. The random and independent 12 observations of Anatolian Water Buffalo took place during October 3<sup>rd</sup> and 10<sup>th</sup> 2012. We recorded on 10 occasions the situation, when Marsh Frogs were present on buffaloes (Tab. 1). Frogs were recorded both on resting and standing mammals in different part of their body including the head. In most cases frogs hunted flies (Fig. 1). Further random observations carried out in the next year confirmed that the described phenomenon only occurs in autumn, when the density of frogs is much higher than during spring (pers. obs.).

Our observations indicate an association between frogs and buffaloes and may have a biological meaning. The observed behaviour was not incidental or loosely structured. Frogs foraged on buffaloes in a similar manner as birds on large mammals (Heatwole, 1965; Dean and MacDonald, 1981; Yosef and Yosef, 1991; Sazima,

2011). The food habits of Marsh Frogs are generalist and the species may change its diet in response to local variation in frequency of available prey items, mainly insects, but sometimes also fish, amphibians, and small mammals (Çiçek and Mermer, 2007; Mollov et al., 2010). Because the diet of the species also includes fly species, and many of them are parasites or main disease vectors for large mammals, including buffaloes (Bengis et al., 2002; Altintas, 2004), the recorded association between frogs and buffaloes can be considered as a possible mutualistic interaction (Bascompte, 2009; Sazima et al., 2010). Mutualistic interactions between large mammals and birds may originate and intensify rapidly under specific local conditions (Bradshaw and White, 2006). Such situations probably also occurred in the Kızılırmak delta, where frogs were present on buffaloes only in autumn, when the density of amphibians is high compared to spring. However, because we did not study the diet of the frogs, we cannot prove that water buffaloes have tangible benefit from the presence of the frogs. Hence, the observed relationship can be also interpreted as commensalism (Dickman, 1992), where only frogs benefit from the buffaloes without affecting them.

The reasons why the associations between frogs and free ranging water buffaloes were not previously reported are unclear. This could be due to frog and buffalo density in one specific area, but also other local factors like density of insects or habitat, like small water bodies constructed by buffaloes during body washing, grazing and excrements (Jansen and Healey, 2003; Hartel and von Wehrden, 2013; Musitelli et al., 2016). Photographs from south Asia and Europe with frogs resting (not foraging) on buffaloes suggest that the occurrence of frogs on buffaloes may be occasional and accidental and the probability of such observations may depend on frog and buffalo densities. However, our observations where in most cases frogs hunt flies present on buffaloes confirm the exist-

**Table 1.** Basic data about the following observations of frogs on buffaloes carried out in the Kızılırmak delta in October 2012.

No. observation	Date	Air temperature (C°)	No. buffaloes	No. buffaloes with frogs	No. frogs on buffaloes	Mean no. frogs per buffalo
1	03.10	17	9	7	31	4.4
2	03.10	20	1	1	27	27.0
3	04.10	17	3	2	9	4.5
4	04.10	21	6	6	14	2.3
5	05.10	18	2	2	5	2.5
6	06.10	18	2	2	2	1.0
7	07.10	16	3	2	5	2.5
8	07.10	23	1	1	19	19.0
9	08.10	24	2	2	13	6.5
10	10.10	21	4	3	22	7.3
Overall mean $\pm$ SD	–	19.5 $\pm$ 2.7	3.3 $\pm$ 2.5	2.8 $\pm$ 2.0	14.7 $\pm$ 9.9	7.7 $\pm$ 8.5



**Fig. 1.** Photographs of the interaction between frogs and buffaloes. Clock-wise: (1) general view of the habitat in the Kızılırmak delta; (2) foraging and resting buffaloes; (3) sitting buffaloes with many frogs on the fur; and (4) foraging frogs and flies on buffalo fur.

ence of an interspecific interaction between amphibians and large mammals. An additional explanation for the observed phenomenon could be the use of buffaloes by frogs as an efficient heat source, which can be important for heterothermic amphibians especially at low ambient temperatures (Sinsch, 1984).

To the best of our knowledge, these are the first observations of an interaction between Marsh Frogs and Water Buffaloes, or even more generally between amphibians and large mammals. However, our data provide the first evidence of such associations. We hope that our note will stimulate further research on this subject.

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